

JC13 Rec'd PCT/PTO 19 APR 2009

**METHOD FOR TREATING A LOAD OF STACKED LIGNEOUS
MATERIAL ELEMENTS, IN PARTICULAR A LOAD OF WOOD BY
HIGH-TEMPERATURE HEAT TREATMENT**

- 5 The present invention relates to a method for treating a load of woody material made up of stacked elements, particularly a load of wood, by high-temperature heat treatment.
- 10 It relates more particularly to a method for treating wood thermally so that it retains or even improves all its characteristics such as its mechanical, acoustic and insulating properties, together with its dimensional stability in the presence of moisture. Such
- 15 a heat treatment allows the mediums that generate microorganisms and mold to be eliminated.

This heat treatment also allows chemical linking between the macromolecular chains of the constituents of the wood in a controlled atmosphere and at a minimum

20 temperature of 230 degrees Celsius. The main qualities acquired during high-temperature heat treatment are of dimensional stability and markedly improved resistance to the kinds of attack that lead to ageing and rotting.

25 The prior art, particularly patent FR-A-2 790 698 filed by the same applicant, already discloses such a device for the high-temperature heat treatment of a woody material. That patent in particular describes an

30 enclosed treatment space which comprises means for processing a load of woody material that is to be treated, this load of woody material delimiting, within said enclosed space, a first volume known as the "raised-pressure chamber", situated upstream of the

35 load that is to be treated and a second volume known as the "recovery chamber", situated downstream of said load, heating means for heating a heat-transfer fluid circulating in said enclosed space, circulating means continuously circulating said heat-transfer fluid,

monitoring means for monitoring the temperature and moisture content of the enclosed space, regulating means for regulating the temperature and humidity of the enclosed treatment space, and sealing means sealing
5 the top and bottom of the load of material.

Such a device works on the principle of continuous circulation of a heat-transfer gas formed of air with its oxygen removed and which is mixed with the
10 combustion gases to provide a neutral atmosphere. Having been heated in successive steps up to a minimum temperature of 230 degrees Celsius, these steps being defined on the basis of parameters associated with the woody material that is to be treated, the heat-transfer
15 gas circulates continuously throughout the treatment cycle, from the point where it is heated up by the heating means, for example by means of a burner, toward the load of woody material that is to be treated, through which it passes at a flow rate and speed which
20 are in equilibrium at every point in its circuit, uniformly supplying it with the heat energy needed for the heat treatment. The treatment cycle requires several passes of the fluid through the load. When this cycle is over, the drop in temperature takes place in
25 successive steps by spraying high-pressure cold water in the heat-transfer gas circuit in the raised-pressure chamber. The pressure within the enclosed space is maintained in the treatment zone by the arrival of a neutral gas which compensates for the reduction in
30 volume of the heat-transfer fluid during this cooling phase.

Although such heat-treatment devices are known, they continue to undergo development aimed at allowing a
35 high level of safety and a level of quality and uniformity of the heat treatment across the various wood loads that there are.

Thus, the object of the invention is to propose a

method for treating a load of woody material made up of stacked elements, particularly a load of wood, by high-temperature heat treatment, which makes it possible to take account of the behavior of the products in terms of their thermal conductivity and their resistance toward releasing their liquid or degradable substances under the effect of high temperature.

To this end, the subject of the present invention is a method for treating a load of woody material made up of stacked elements, particularly a load of wood, by high-temperature heat treatment, using an enclosed treatment space which comprises means for processing a load of woody material that is to be treated, this load of woody material delimiting; within said enclosed space, a first volume known as the "raised-pressure chamber", situated upstream of the load that is to be treated and a second volume known as the "recovery chamber", situated downstream of said load, heating means for heating a heat-transfer fluid circulating in said enclosed space, circulating means continuously circulating said heat-transfer fluid, monitoring means for monitoring the temperature and moisture content of the enclosed space, regulating means for regulating the temperature and humidity of the enclosed treatment space, and sealing means sealing the top and bottom of the load of material, said method comprising the steps consisting:

in permanently monitoring and measuring the atmosphere in each of said chambers using the temperature monitoring means then in comparing the data emanating from these monitoring means so as to act simultaneously and uniformly on the altering of the power of the means for heating and, if any, on the cooling, of the heat-transfer gas by the regulating means thus running a heat-treatment cycle, the rise in temperature of which is either linear or in steps, the temperature step levels and their duration being preestablished; this

rise in temperature is then governed as a function of the behavior of the load of woody material in terms of its thermal conductivity and as a function of equilibrium between the flow rate and the speed of the heat-transfer fluid between the two chambers.

According to an advantageous arrangement, each of the temperature levels in the treatment cycle is reached when there is equilibrium between the temperature in the raised-pressure chamber and the temperature in the recovery chamber, and said equilibrium is determined using the following formulae:

$T_1 = T_2 - \Delta^{\circ}\text{C}$ when the temperature in the treatment cycle is rising, and

$T_2 = T_1 + \Delta'^{\circ}\text{C}$ when the temperature in the treatment cycle is falling, where

Δ and Δ' are temperature constants ranging between 5 and 25 degrees Celsius.

According to a preferred embodiment, the constants Δ and Δ' are respectively equal to 5 degrees Celsius and 20 degrees Celsius.

Still according to the invention, progression to a level at least equal to 100 degrees Celsius is permitted only if the volume of the enclosed space contains an oxygen content of below 3%.

According to another advantageous arrangement, if an incident concerning the heating means is detected above a mean temperature in excess of 120 degrees Celsius, the temperature regulating means are set off until a mean temperature of below 100 degrees Celsius is detected in the chambers before any resumption of the treatment cycle is permitted.

According to yet another advantageous arrangement, the electronic control means controlling the oven are also

connected to computerized equipment that allows all the data from the sensors arranged in the enclosed space to be printed out during a treatment cycle together with the temperature curves, in real time.

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According to another advantageous arrangement, the speed at which the heat-transfer fluid circulates is kept constant in the enclosed treatment space by monitoring said speed and acting on the flow rate of the means that propel said heat-transfer fluid.

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The characteristics of the invention and mentioned hereinabove, together with others, will become more clearly apparent upon reading the following description of an exemplary embodiment, with reference to the single attached figure which is a schematic depiction in vertical section of a device for the high-temperature heat treatment of a woody material.

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The single figure shows an enclosed space 1 comprising four vertical walls 2 and a roof 3. At least one of the vertical walls 2 of the enclosed space is provided with a door 4 so that the woody material 5 that is to be treated can be loaded in.

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This load of woody material 5 is made up of wooden planks 6 stacked on top of one another to form more or less a parallelepipedal structure intended to be placed inside the enclosed space 1.

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Advantageously, the planks 6 are placed in such a way that their length is in the longitudinal direction of the enclosed space, and they are separated from one another by spacer pieces in the form of spacers 7 placed in their transverse direction. The thickness of these spacers 7 is defined according to the thickness of the wood that is to be treated, the dimensions of the load and the physical parameters concerned with the circulation of the fluid in the enclosed space 1 and

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through said load 5.

5 The load of woody material to be treated 5 delimits, within the enclosed space, a first volume 8 known as the "raised-pressure chamber", situated upstream of the load 5, and a second volume 9, known as the "recovery chamber", situated downstream of the load 5.

10 Furthermore, said enclosed space 1 is provided, as mentioned in patent application FR-A-2 790 698, which forms an integral part of this application by reference, with heating means 10 for heating a heat-transfer fluid circulating in said enclosed space 1, circulating means 11 for continuously circulating said
15 heat-transfer fluid, means for monitoring the temperature and moisture content of the enclosed space, regulating means 12 for regulating the temperature and humidity of the enclosed treatment space 1 and sealing means sealing the top and bottom of the load of
20 material, thus preventing the heat-transfer fluid from following its preferred route out of the load.

In order to illustrate the abovementioned means, it will be noted that the means 10 for heating the heat-transfer
25 fluid comprise at least one gas burner arranged in the upper part of the enclosed space 1 in a chamber 13 known as the heating chamber, while the circulating means 11 consist of at least one fan intended to draw the heat-transfer fluid out of the recovery chamber 9 and propel it
30 into the heating chamber 13. The regulating means consist, for example, of a horizontal high-pressure water spray boom 12 situated in the raised-pressure chamber 8. This spray boom 12 is provided with a number of nozzles for spraying a high flow rate mist of cold or chilled water.

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Programmable electronic control means, not depicted, allow the temperature variation step levels and the moisture content in the enclosed treatment space to be controlled.

This enclosed treatment space 1 is advantageously driven by a method according to the invention that consists in permanently monitoring and measuring the atmosphere in each of said chambers using the temperature monitoring means then in comparing the data emanating from these monitoring means so as to act simultaneously and uniformly on the altering of the power of the means 10 for heating and, if any, on the cooling, of the heat-transfer gas by the regulating means 12 thus running a heat-treatment cycle, the temperature step levels and the duration of which are preestablished, as a function of the behavior of the load of woody material 5 in terms of its thermal conductivity and of equilibrium between the flow rate and the speed of the heat-transfer fluid between the two chambers 8 and 9.

According to an alternative form of embodiment, it is understood that the rise in temperature may be achieved linearly.

It will be noted that the monitoring means are, in particular, temperature, pressure, humidity and oxygen-analysis sensors arranged in the two chambers 8 and 9 making it possible to establish the authority to set off the heating means 10 and the circulating means 11 for continuously circulating the fluid or, on the other hand, disable these and engage the regulating means 12 for regulating temperature and humidity when, in particular, the temperature in the recovery chamber exceeds the temperature in the raised-pressure chamber during the temperature rise of the pre-established treatment cycle.

The various pressure and temperature zones created by the pressure drop on passing through the products that are to be treated 5 and by the exchange of heat energy between the heat-transfer gas and said products allow for easy and precise control of the operation and of

the treatment parameters.

Thus, the level achieved during a preestablished treatment cycle and built into the electronic control means is determined by equilibrium between the temperatures in the two chambers. This equilibrium is determined according to the rule $T_1 = T_2 - \Delta^\circ\text{C}$ when the temperature is rising, and according to the rule $T_2 = T_1 + \Delta' ^\circ\text{C}$ when it is falling, where T_1 corresponds to the temperature in the raised-pressure chamber and T_2 corresponds to the temperature in the recovery chamber and Δ and Δ' correspond to temperature constants illustrated hereinbelow.

One mode of operation according to the method of the present invention is illustrated hereinbelow for a woody material such as wood with a moisture content of 12 to 14%.

Levels were determined for executing a treatment cycle comprising a rise in temperature up to 230 degrees Celsius then a controlled drop in temperature as follows:

25	1 st level	40°C	Duration: 1 hour after equilibrium	Moisture content 60%
	2 nd level	60°C	Duration: 2 hours after equilibrium	Moisture content 60%
	3 rd level	100°C	Duration: 2 hours after equilibrium	Moisture content 40%
	4 th level	140°C	Duration: 1 hour after equilibrium	$O_2 < 3$ and moisture content 20%
	5 th level	170°C	Equilibrium	
30	6 th level	190°C	Equilibrium	
	7 th level	210°C	Equilibrium	
	8 th level	230°C	Equilibrium	

As soon as the oven is brought into operation, the volume of air contained within the enclosed treatment

space is set into circulation using the fans, said enclosed treatment space being kept at a pressure above atmospheric pressure.

- 5 Tappings are made in said chambers in order to collect data relating in particular to the flow rate and speed of the heat-transfer fluid inside the enclosed space.

10 The volume of air is circulated until the determined flow rate and the determined speed in the two chambers 8 and 9 reach equilibrium, thus ensuring uniform transfer of heat to all points of the load of woody material 5.

- 15 Finally, the treatment cycle begins by setting off the heating means 10 that heat the heat-transfer fluid. Constant measurement of the oxygen content of the heat-transfer fluid in the raised-pressure chamber 8 and constant measurement of the carbon monoxide CO gas
20 content installed in the upper part of the chambers 8 and 9 allows operation of the heating means 10 to be disabled if the oxygen O or carbon monoxide CO gas concentrations exceed a given level.

- 25 If the temperature in the enclosed space reaches 45 degrees Celsius, which corresponds to the threshold for the first temperature level in the chamber T1, the burners 10 reduce their power and if the temperature continues to rise, the sprinkling boom 12 comes into
30 action and sprinkles cold water and then, if necessary, chilled water.

The temperature level for the cycle is reached, as mentioned hereinabove, when the temperature in the
35 raised-pressure chamber 8 is equal to the temperature in the recovery chamber 9 minus a temperature constant Δ preferably equal to 5 degrees Celsius. This temperature level is maintained for the determined duration, in this example one hour, regulating this

temperature using the means described hereinabove.

As soon as the time duration for the level has elapsed, the electronic control means trigger the rise in temperature to the next level above, under the same operating conditions, and so on until the temperature of 230 degrees Celsius is reached.

It will advantageously be noted that progression from the level of 100 degrees Celsius is preferably subject to the condition that the volume of the enclosed space contains less than 3% oxygen.

Furthermore, the enclosed space of the oven is kept at a pressure of 4 ± 1 mmCE during the treatment cycle. To do this, said enclosed space is provided in a known way with a calibrated relief valve to allow any surplus heat-transfer gas generated by the burners to be discharged.

After the treatment temperature has been reached, the temperature in the enclosed space is lowered in steps, by spraying cold or chilled water into the heat-transfer fluid circuit using the sprinkling boom. These temperature-lowering levels are, for example, defined as follows: 200, 170, 130, 90 and 50 degrees Celsius.

As already mentioned hereinabove, progression from one level to the next takes place when the equilibrium of the temperature T2 in the recovery chamber 9 is preferably equal to the temperature T1 recorded in the raised-pressure chamber 8 plus a temperature constant Δ' defined, for example, as 20 degrees Celsius.

It will be noted that when the temperature is dropping, the electronic control means record the pressure in the enclosed space and compensate for the depression brought about by the reduction in volume of heat-transfer gas by automatically sending in nitrogen to

maintain the pressure in the chamber.

5 In order to ensure safety within the enclosed space,
the method according to the present invention makes
sure, that if there is an incident involving the
heating means when the mean temperature of the chambers
is above 120 degrees Celsius, the temperature of the
enclosed space is dropped in a similar way to that
described hereinabove using the sprinkling booms until,
10 in particular, a mean chamber temperature of less than
100 degrees Celsius is reached before any resumption of
a treatment cycle is permitted.

15 The electronic control means controlling the oven are
also connected to computerized equipment that allows
all the data from the sensors arranged in the enclosed
space to be printed out during a treatment cycle
together with the temperature curves, in real time.

20 It will be noted that, in order to obtain good results
in terms of the quality and uniformity of the heat
treatment, it is preferable not to mix products of
different thicknesses or species in the same load.

25 One of the main advantages of the technique lies in the
principle of operation of the oven, which causes it to
operate in a natural way according to the behavior of
the products in terms of their thermal conductivity and
resistance to releasing their liquid or degradable
30 substances under the effect of high temperature. The
suite of electronic and computerized means acts only as
a means of monitoring the various safety features,
permitting or preventing the requested actions and
relaying information about the operation of the oven.

35 Such a method advantageously allows the treatment of
very different species without having produced specific
programs. The way in which such an oven works should
automatically adapt itself to the requirements of the

products, although it may be necessary to alter the temperature levels and the durations for which they are maintained.

- 5 Although the invention has been described in conjunction with one particular embodiment, it encompasses all technical equivalents of the means described.
- 10 In order to allow the suite of detection and control means of a treatment device according to the invention to yield the expected results, the speed at which the heat-transfer fluid circulates is kept constant in the enclosed treatment space and through the load of woody
- 15 material by action on the flow rate of the means that drive the heat-transfer fluid.